EFFICIENT TECHNIQUE FOR ESTIMATING ELEVATION ANGLE WHEN USING A BROAD BEAM FOR SEARCH IN A RADAR
Eli Brookner
Application No. 10/683,507

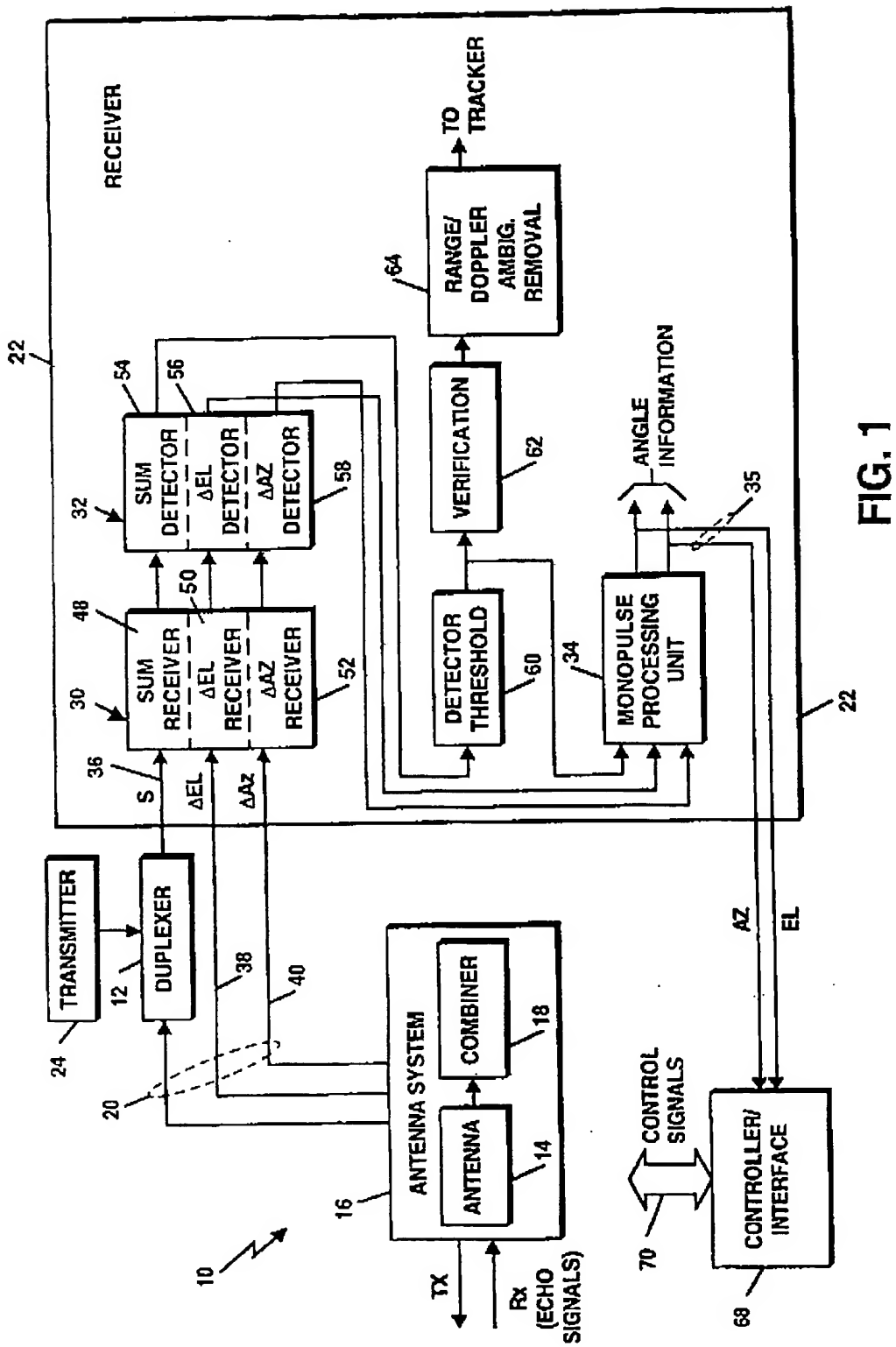

FIG. 1

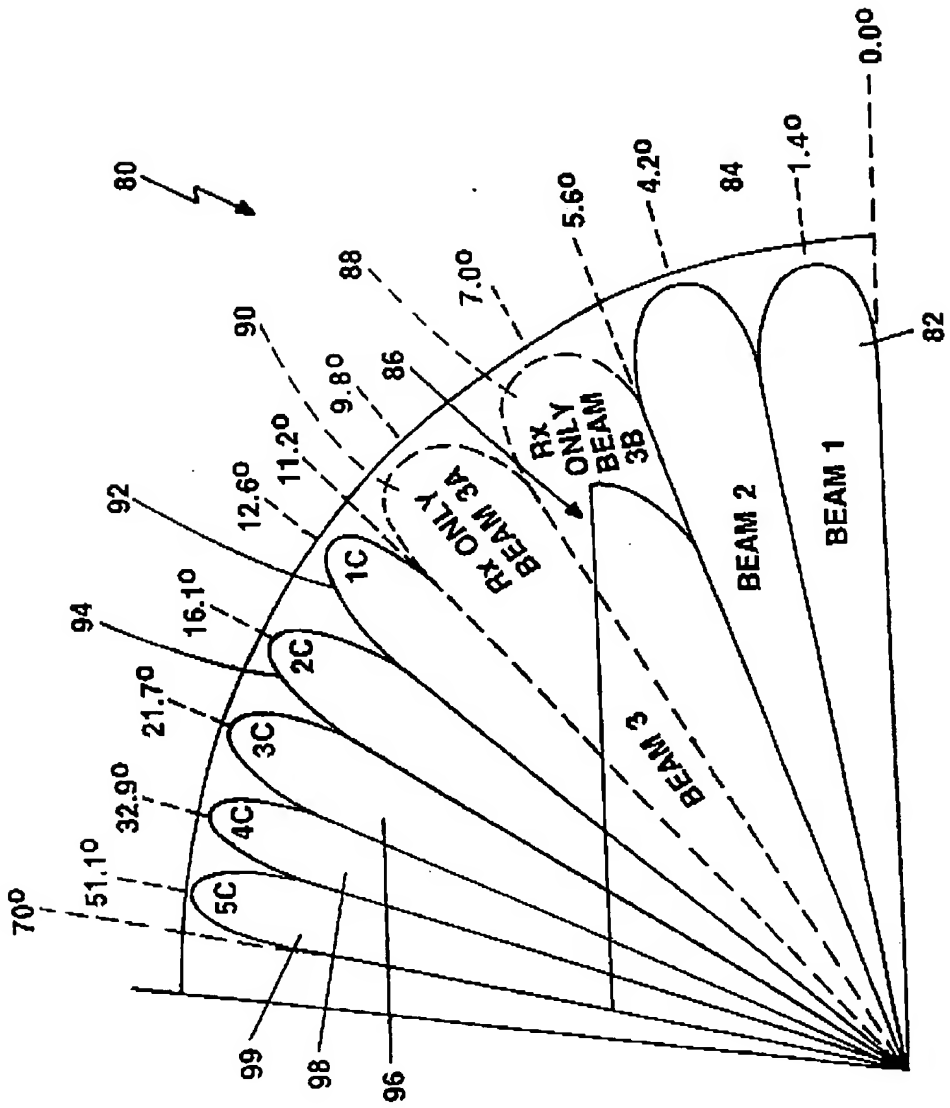
80
88
90
86
92
94
96
98
99
82
84
0.0°
1.4°
4.2°
5.6°
7.0°
9.8°
11.2°
12.6°
16.1°
21.7°
32.9°
51.1°
70°
1C
2C
3C
4C
5C
RX ONLY BEAM 3A
Rx ONLY BEAM 3B
BEAM 1
BEAM 2
BEAM 3

FIG. 2

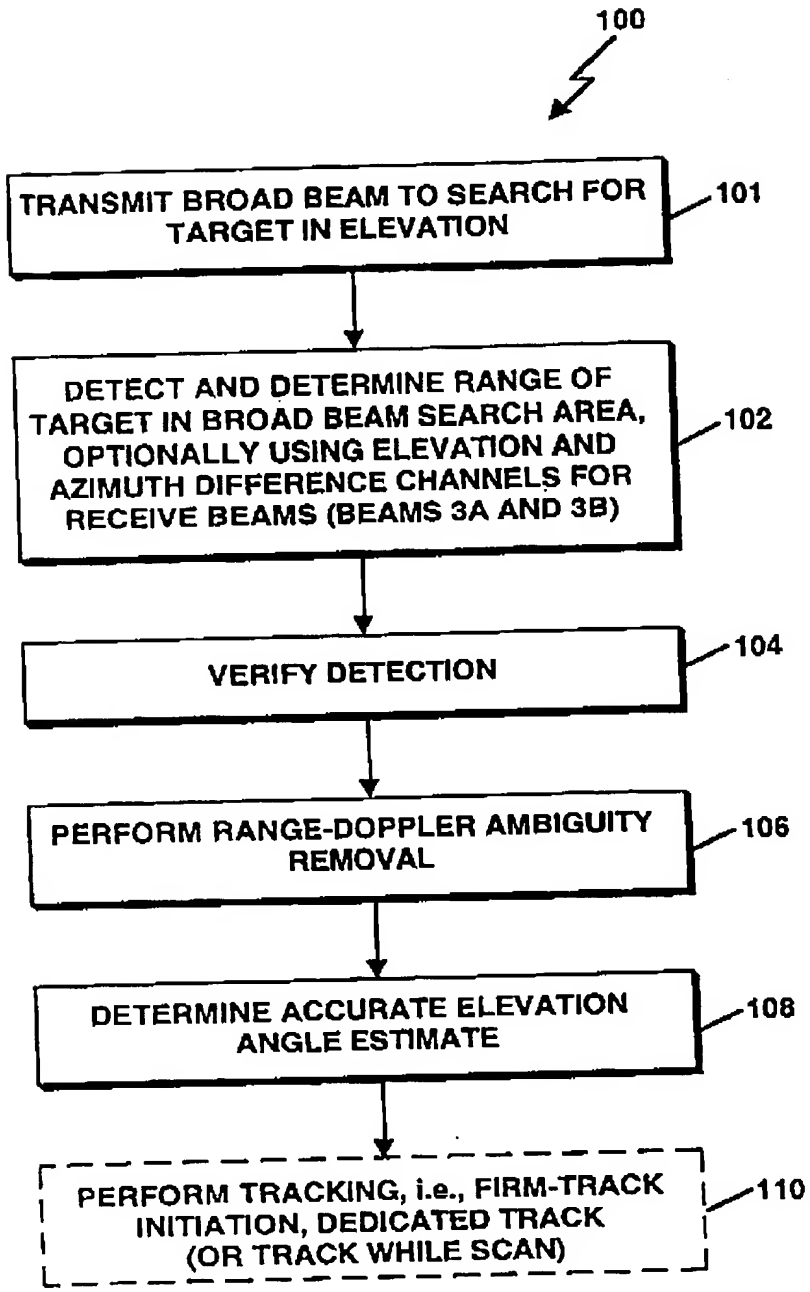
100
TRANSMIT BROAD BEAM TO SEARCH FOR TARGET IN ELEVATION
101
DETECT AND DETERMINE RANGE OF TARGET IN BROAD BEAM SEARCH AREA, OPTIONALLY USING ELEVATION AND AZIMUTH DIFFERENCE CHANNELS FOR RECEIVE BEAMS (BEAMS 3A AND 3B)
102
VERIFY DETECTION
104
PERFORM RANGE-DOPPLER AMBIGUITY REMOVAL
106
DETERMINE ACCURATE ELEVATION ANGLE ESTIMATE
108
PERFORM TRACKING, i.e., FIRM-TRACK INITIATION, DEDICATED TRACK (OR TRACK WHILE SCAN)
110

FIG. 3

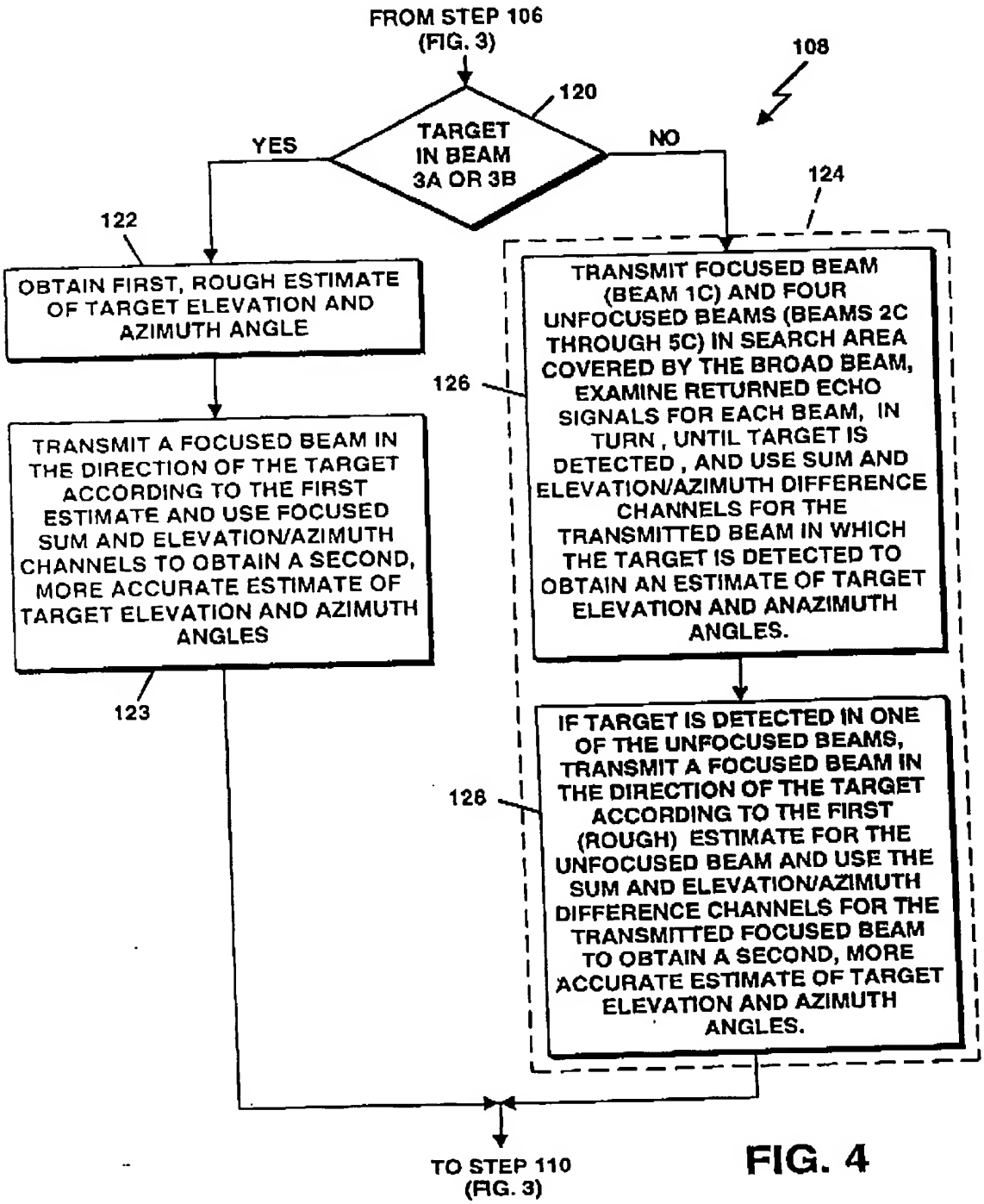
FROM STEP 106
(FIG. 3)
108
120
TARGET
IN BEAM
3A OR 3B
YES
NO
124
122
OBTAIN FIRST, ROUGH ESTIMATE OF TARGET ELEVATION AND AZIMUTH ANGLE
TRANSMIT FOCUSED BEAM (BEAM 1C) AND FOUR UNFOCUSED BEAMS (BEAMS 2C THROUGH 5C) IN SEARCH AREA COVERED BY THE BROAD BEAM, EXAMINE RETURNED ECHO SIGNALS FOR EACH BEAM, IN TURN, UNTIL TARGET IS DETECTED, AND USE SUM AND ELEVATION/AZIMUTH DIFFERENCE CHANNELS FOR THE TRANSMITTED BEAM IN WHICH THE TARGET IS DETECTED TO OBTAIN AN ESTIMATE OF TARGET ELEVATION AND ANAZIMUTH ANGLES.
126
TRANSMIT A FOCUSED BEAM IN THE DIRECTION OF THE TARGET ACCORDING TO THE FIRST ESTIMATE AND USE FOCUSED SUM AND ELEVATION/AZIMUTH CHANNELS TO OBTAIN A SECOND, MORE ACCURATE ESTIMATE OF TARGET ELEVATION AND AZIMUTH ANGLES
123
IF TARGET IS DETECTED IN ONE OF THE UNFOCUSED BEAMS, TRANSMIT A FOCUSED BEAM IN THE DIRECTION OF THE TARGET ACCORDING TO THE FIRST (ROUGH) ESTIMATE FOR THE UNFOCUSED BEAM AND USE THE SUM AND ELEVATION/AZIMUTH DIFFERENCE CHANNELS FOR THE TRANSMITTED FOCUSED BEAM TO OBTAIN A SECOND, MORE ACCURATE ESTIMATE OF TARGET ELEVATION AND AZIMUTH ANGLES.
128
TO STEP 110
(FIG. 3)

FIG. 4

EFFICIENT TECHNIQUE FOR ESTIMATING ELEVATION ANGLE WHEN USING A BROAD BEAM FOR SEARCH IN A RADAR
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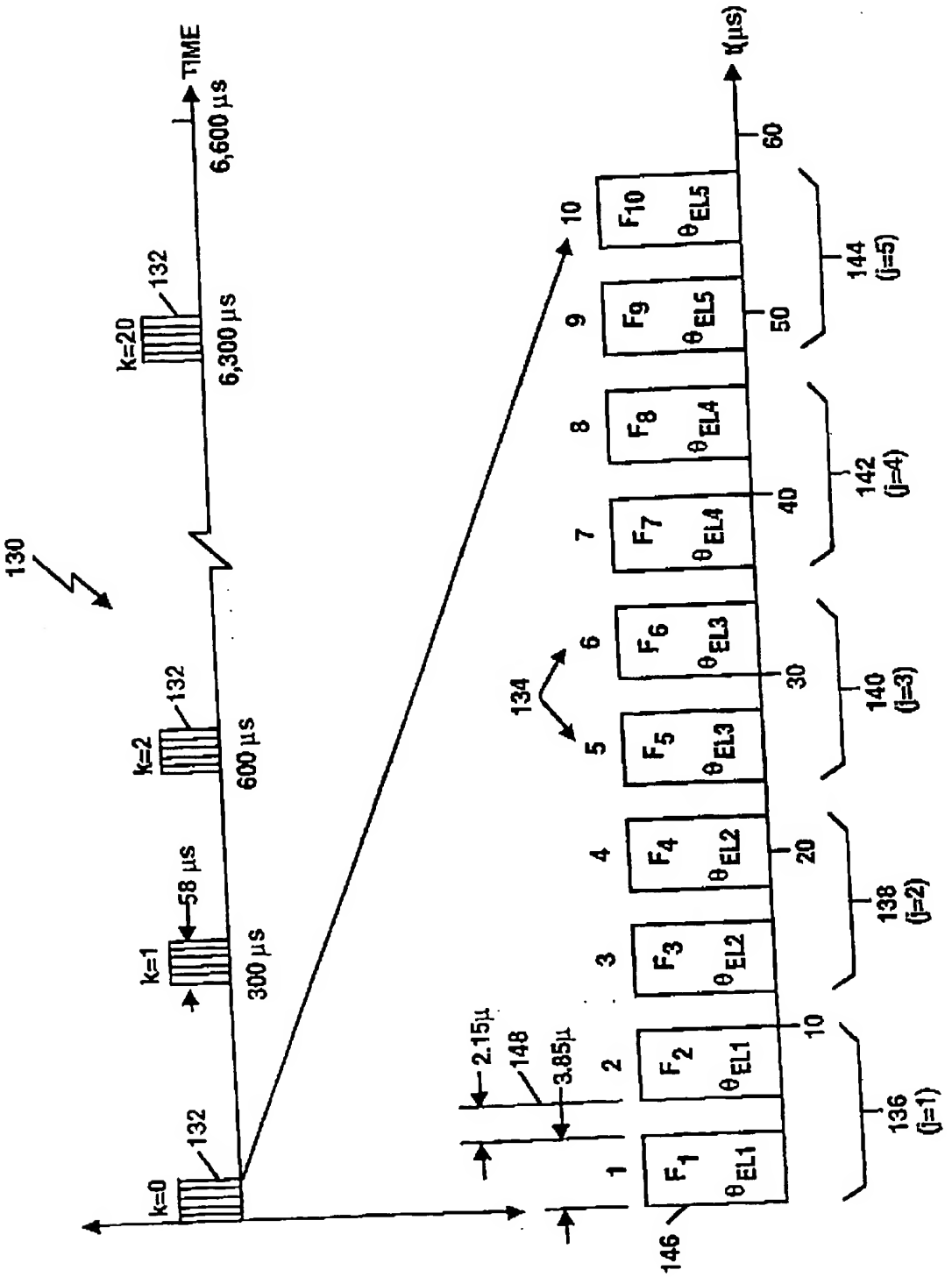

FIG. 5

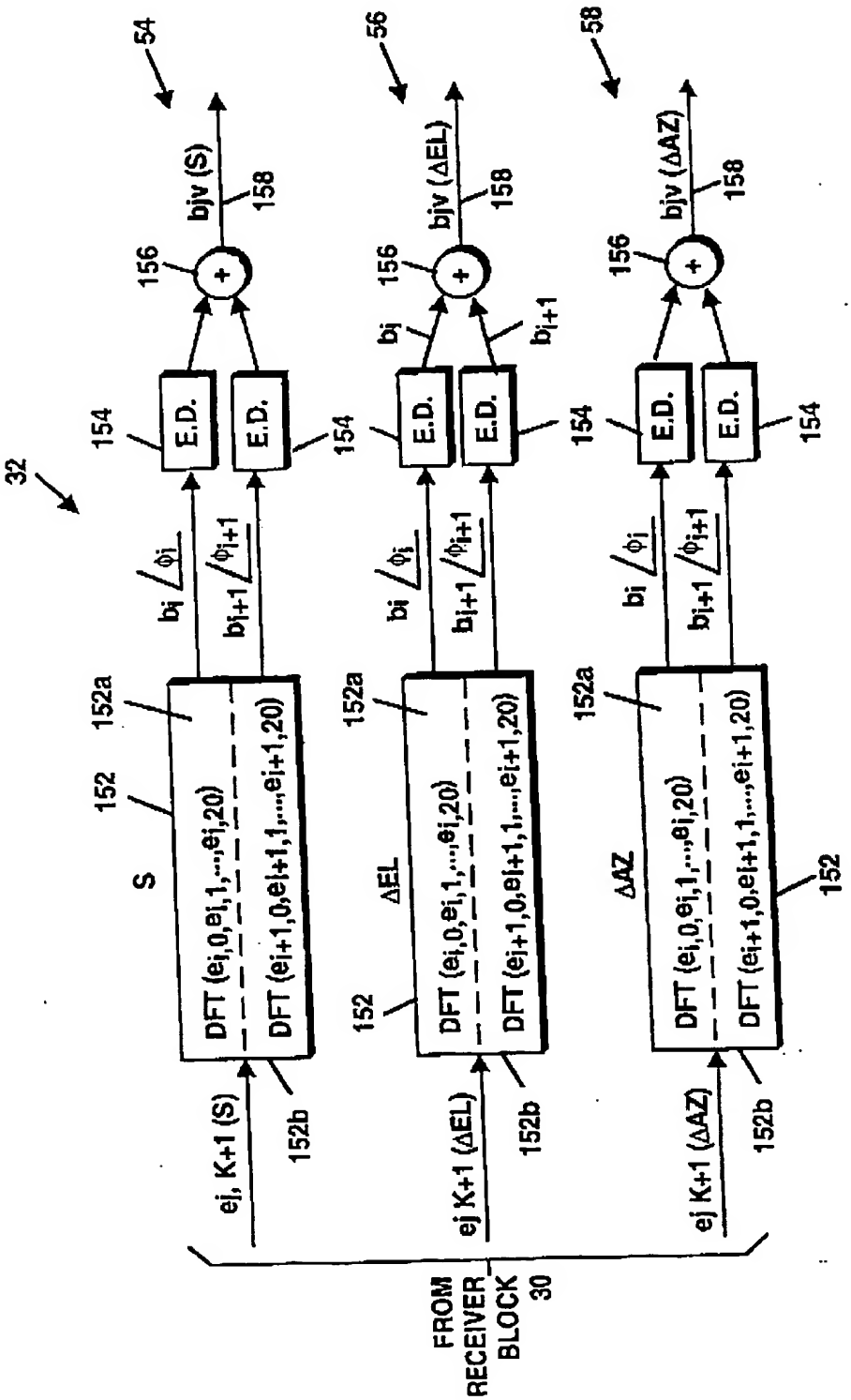
32
54
56
58
154
E.D.
156
158
bjv (S)
bjv (ΔEL)
bjv (ΔAZ)
bj
bj+1
φi
φi+1
152a
152
S
ΔEL
ΔAZ
DFT (ei,0,ei,1,...,ei,20)
DFT (ei+1,0,ei+1,1,...,ei+1,20)
ej, K+1 (S)
ej K+1 (ΔEL)
ej K+1 (ΔAZ)
152b
FROM RECEIVER BLOCK 30

FIG. 6

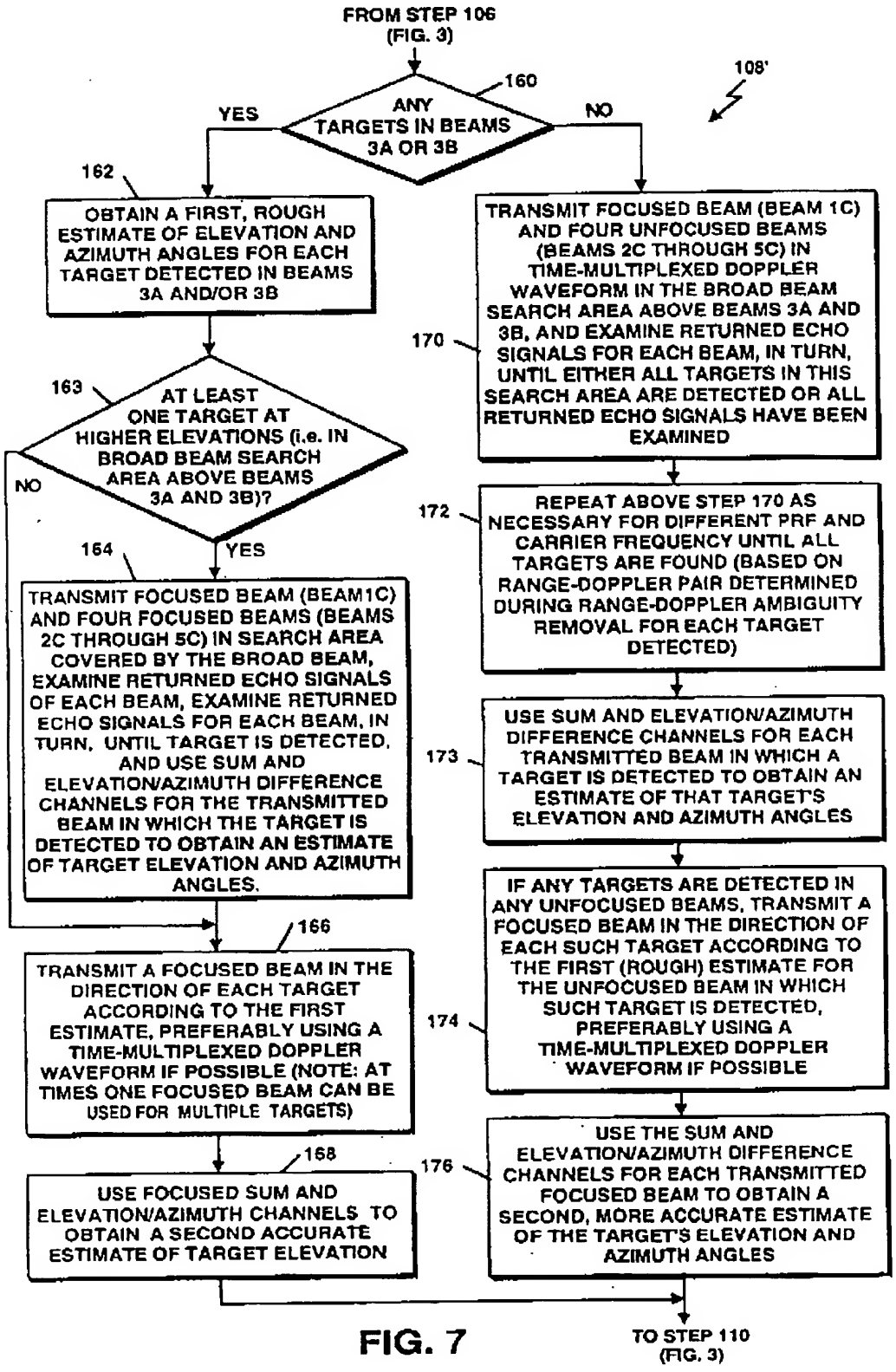
FROM STEP 106 (FIG. 3)
108'
160
ANY TARGETS IN BEAMS 3A OR 3B
YES
NO
162
OBTAIN A FIRST, ROUGH ESTIMATE OF ELEVATION AND AZIMUTH ANGLES FOR EACH TARGET DETECTED IN BEAMS 3A AND/OR 3B
163
AT LEAST ONE TARGET AT HIGHER ELEVATIONS (i.e. IN BROAD BEAM SEARCH AREA ABOVE BEAMS 3A AND 3B)?
NO
YES
164
TRANSMIT FOCUSED BEAM (BEAM1C) AND FOUR FOCUSED BEAMS (BEAMS 2C THROUGH 5C) IN SEARCH AREA COVERED BY THE BROAD BEAM, EXAMINE RETURNED ECHO SIGNALS OF EACH BEAM, EXAMINE RETURNED ECHO SIGNALS FOR EACH BEAM, IN TURN, UNTIL TARGET IS DETECTED, AND USE SUM AND ELEVATION/AZIMUTH DIFFERENCE CHANNELS FOR THE TRANSMITTED BEAM IN WHICH THE TARGET IS DETECTED TO OBTAIN AN ESTIMATE OF TARGET ELEVATION AND AZIMUTH ANGLES.
166
TRANSMIT A FOCUSED BEAM IN THE DIRECTION OF EACH TARGET ACCORDING TO THE FIRST ESTIMATE, PREFERABLY USING A TIME-MULTIPLEXED DOPPLER WAVEFORM IF POSSIBLE (NOTE: AT TIMES ONE FOCUSED BEAM CAN BE USED FOR MULTIPLE TARGETS)
168
USE FOCUSED SUM AND ELEVATION/AZIMUTH CHANNELS TO OBTAIN A SECOND ACCURATE ESTIMATE OF TARGET ELEVATION
TRANSMIT FOCUSED BEAM (BEAM 1C) AND FOUR UNFOCUSED BEAMS (BEAMS 2C THROUGH 5C) IN TIME-MULTIPLEXED DOPPLER WAVEFORM IN THE BROAD BEAM SEARCH AREA ABOVE BEAMS 3A AND 3B, AND EXAMINE RETURNED ECHO SIGNALS FOR EACH BEAM, IN TURN, UNTIL EITHER ALL TARGETS IN THIS SEARCH AREA ARE DETECTED OR ALL RETURNED ECHO SIGNALS HAVE BEEN EXAMINED
170
REPEAT ABOVE STEP 170 AS NECESSARY FOR DIFFERENT PRF AND CARRIER FREQUENCY UNTIL ALL TARGETS ARE FOUND (BASED ON RANGE-DOPPLER PAIR DETERMINED DURING RANGE-DOPPLER AMBIGUITY REMOVAL FOR EACH TARGET DETECTED)
172
USE SUM AND ELEVATION/AZIMUTH DIFFERENCE CHANNELS FOR EACH TRANSMITTED BEAM IN WHICH A TARGET IS DETECTED TO OBTAIN AN ESTIMATE OF THAT TARGET'S ELEVATION AND AZIMUTH ANGLES
173
IF ANY TARGETS ARE DETECTED IN ANY UNFOCUSED BEAMS, TRANSMIT A FOCUSED BEAM IN THE DIRECTION OF EACH SUCH TARGET ACCORDING TO THE FIRST (ROUGH) ESTIMATE FOR THE UNFOCUSED BEAM IN WHICH SUCH TARGET IS DETECTED, PREFERABLY USING A TIME-MULTIPLEXED DOPPLER WAVEFORM IF POSSIBLE
174
USE THE SUM AND ELEVATION/AZIMUTH DIFFERENCE CHANNELS FOR EACH TRANSMITTED FOCUSED BEAM TO OBTAIN A SECOND, MORE ACCURATE ESTIMATE OF THE TARGET'S ELEVATION AND AZIMUTH ANGLES
176
TO STEP 110 (FIG. 3)

FIG. 7

MULTIPLE RADAR COMBINING FOR INCREASED RANGE, RADAR SENSITIVITY AND ANGLE ACCU Y
Eli Brookner et al.
Application No. 10/684,081

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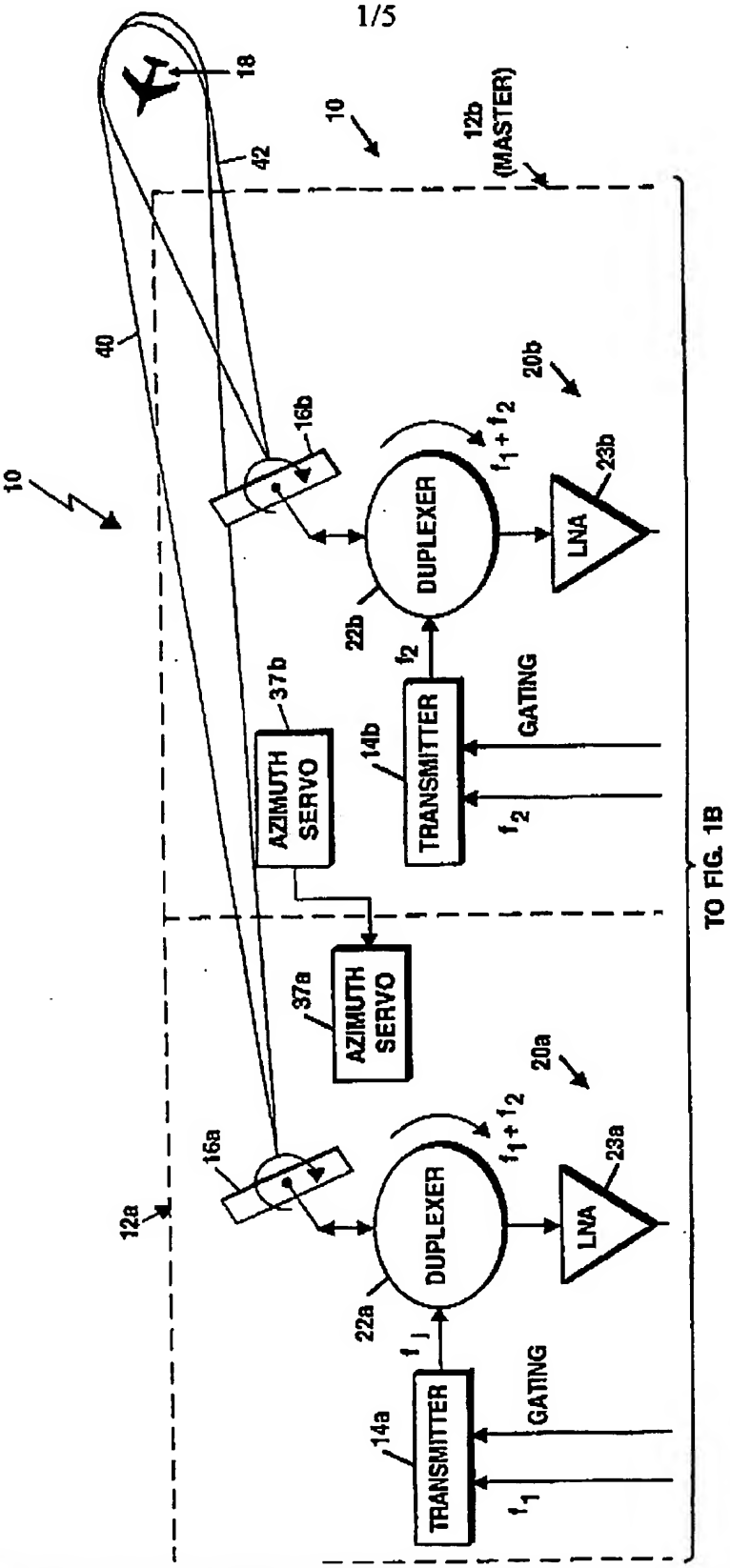

FIG. 1A

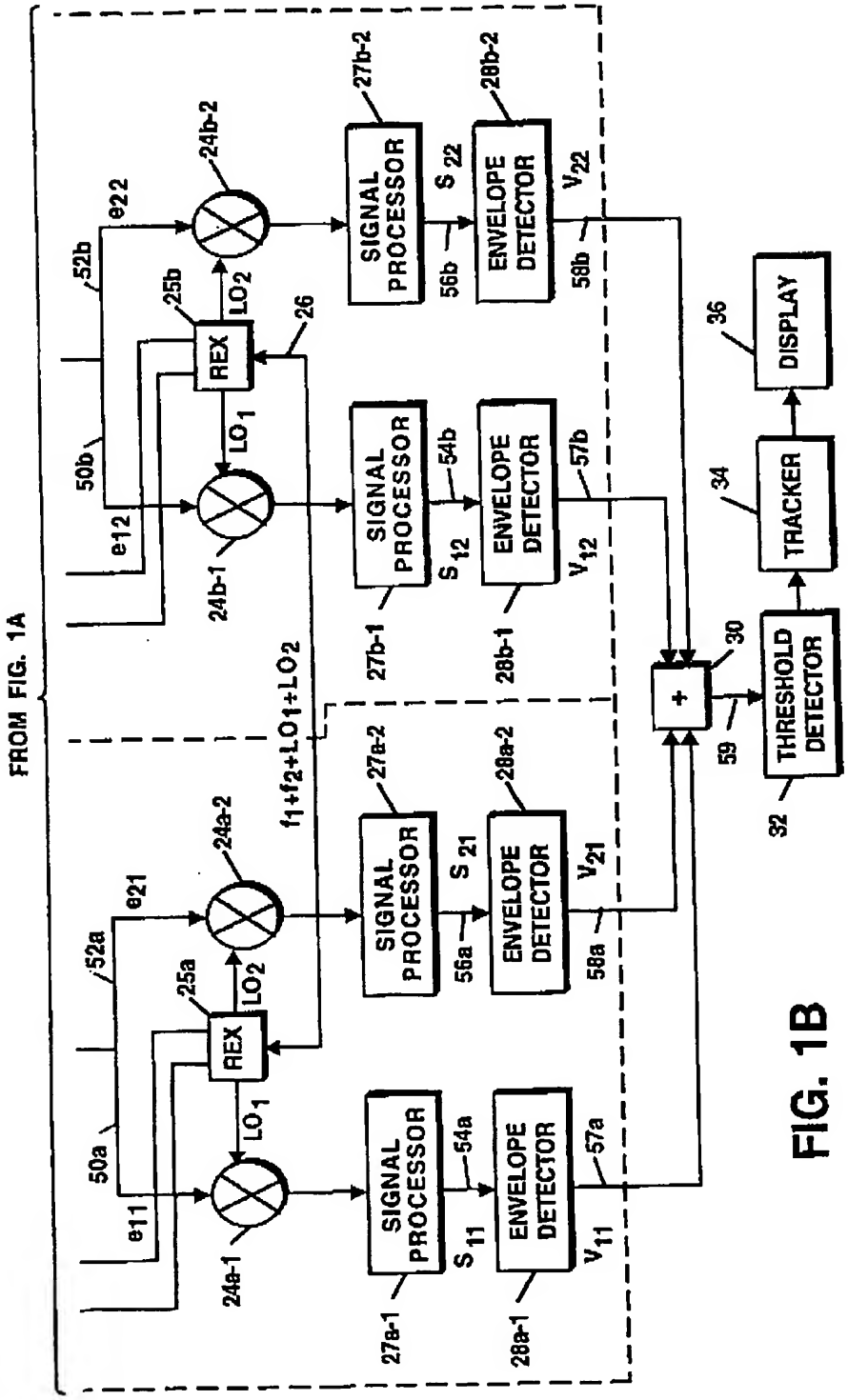
FROM FIG. 1A
$f_1+f_2+LO_1+LO_2$
e22
e12
e21
e11
24b-2
24b-1
24a-2
24a-1
52b
50b
52a
50a
25b
25a
REX
LO_2
LO_1
26
SIGNAL PROCESSOR
ENVELOPE DETECTOR
27b-2
28b-2
27b-1
28b-1
27a-2
28a-2
27a-1
28a-1
S_{22}
S_{12}
S_{21}
S_{11}
V_{22}
V_{12}
V_{21}
V_{11}
56b
54b
57b
58b
56a
54a
57a
58a
+
30
59
THRESHOLD DETECTOR
92
TRACKER
34
DISPLAY
36

FIG. 1B

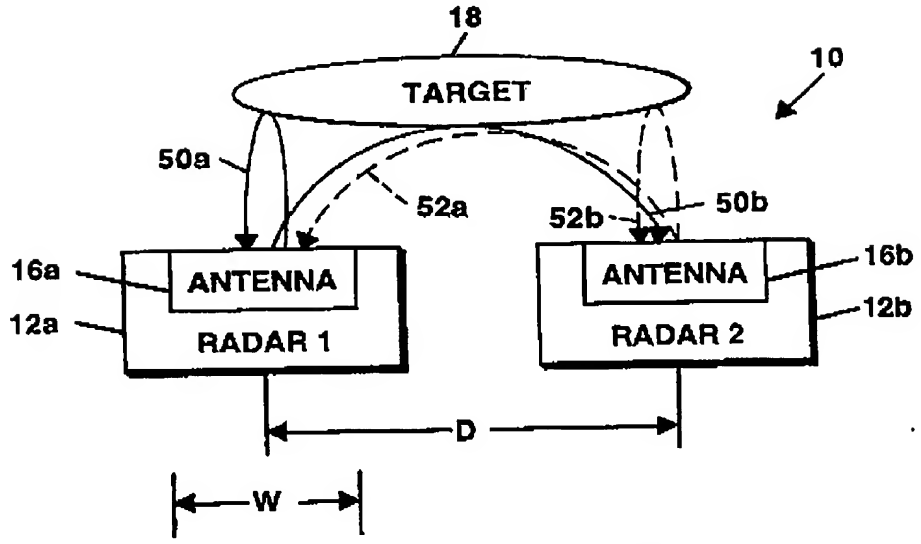
18
TARGET
10
50a
52a
52b
50b
16a
ANTENNA
RADAR 1
12a
ANTENNA
RADAR 2
16b
12b
D
W

FIG. 2

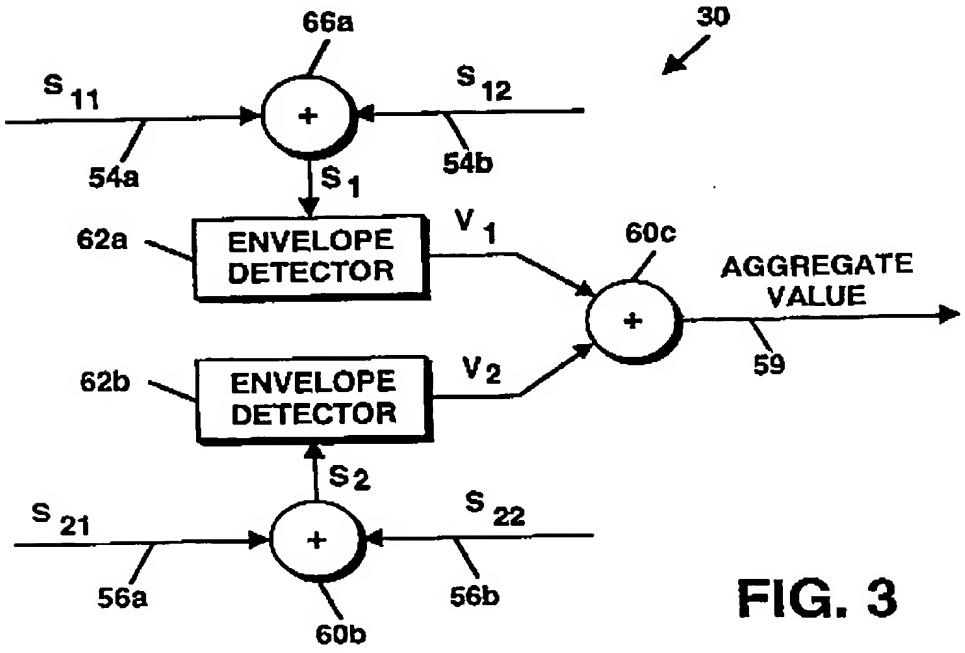
66a
30
S 11
S 12
+
54a
54b
S 1
62a
ENVELOPE DETECTOR
V 1
60c
AGGREGATE VALUE
+
59
62b
ENVELOPE DETECTOR
V 2
S2
S 21
S 22
+
56a
56b
60b

FIG. 3

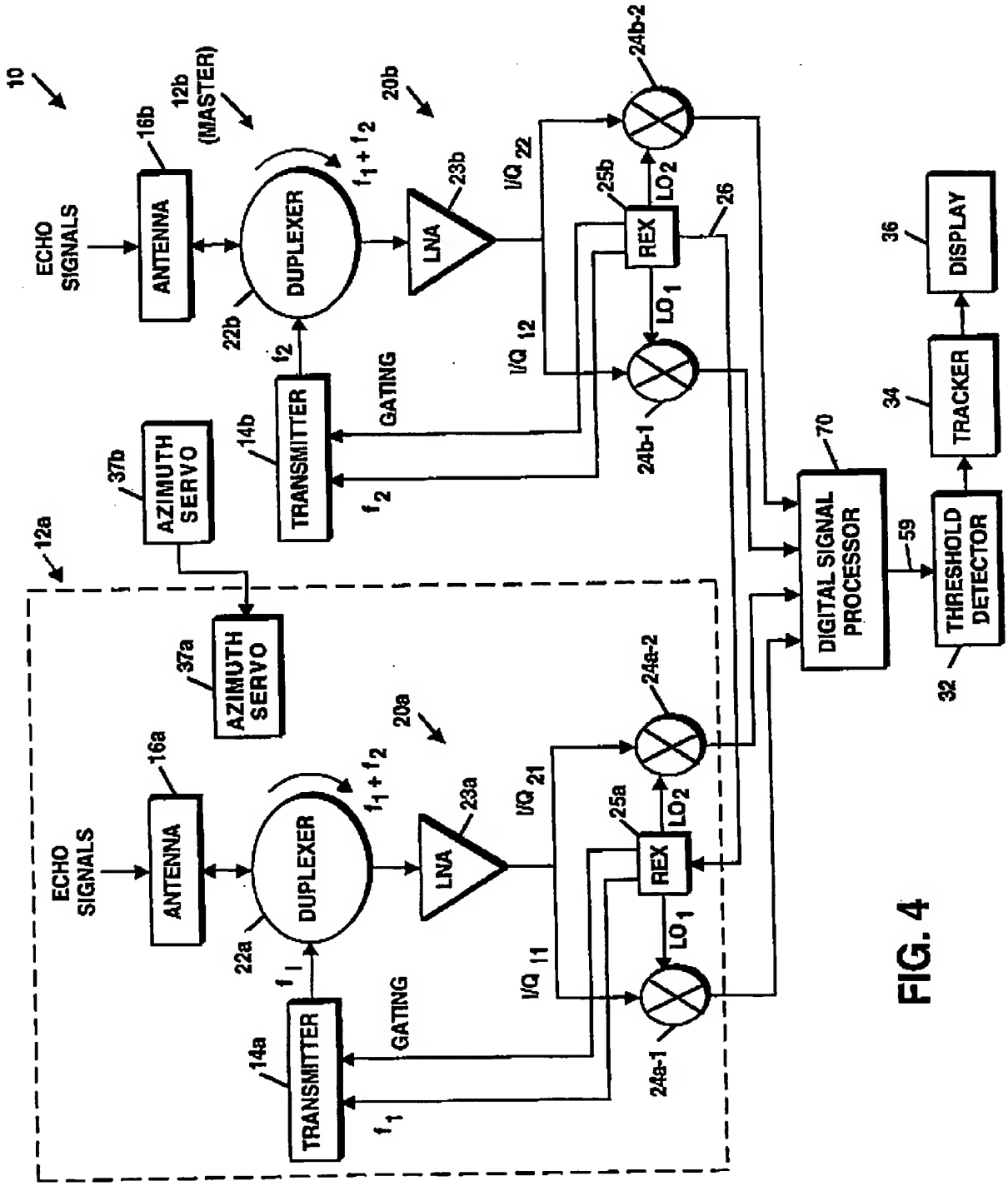
10
12b (MASTER)
20b
16b
ECHO SIGNALS
ANTENNA
DUPLEXER
$f_1 + f_2$
LNA
23b
I/Q 22
24b-2
25b
REX
LO_2
26
LO_1
I/Q 12
24b-1
22b
f_2
GATING
TRANSMITTER
14b
37b
AZIMUTH SERVO
12a
37a
AZIMUTH SERVO
20a
16a
ECHO SIGNALS
ANTENNA
DUPLEXER
$f_1 + f_2$
LNA
23a
I/Q 21
24a-2
25a
REX
LO_2
LO_1
I/Q 11
24a-1
22a
f_1
GATING
TRANSMITTER
14a
f_1
DIGITAL SIGNAL PROCESSOR
70
59
THRESHOLD DETECTOR
32
TRACKER
34
DISPLAY
36

FIG. 4

Mode	Carrier Frequencies for Radar 1 (f_1) and Radar 2 (f_2)	Coherent or Incoherent on Transmit	Receiver Processing of S_{11}, S_{12} and S_{21}, S_{22}	How Waveforms Transmitted	Type of Target	SNR Sensitivity Improvement (dB)
Search/ Track	$f_1 \neq f_2$	Incoherent	Incoherent (as shown in FIG. 1)	Simultaneously	Non-fluctuating	~ 6
Search/ Track	$f_1 \neq f_2$	Incoherent	Coherent + Incoherent (as shown in FIG. 3)	Simultaneously	Non-fluctuating	~ 6
Track	$f_1 = f_2$	Coherent	Coherent	Simultaneously	Non-fluctuating	~ 9
Track	$f_1 = f_2$	Coherent	Coherent + Incoherent	Simultaneously	Non-fluctuating	~ 9
Search/ Track	$f_1 = f_2$	Incoherent	Incoherent	Sequentially	Non-fluctuating	~ 6
Search/ Track	$f_1 = f_2$	Incoherent	Coherent + Incoherent	Sequentially	Non-fluctuating	~ 6
Search/ Track	$f_1 \neq f_2$	Incoherent	Incoherent	Simultaneously	Swerling-II	8.7

FIG. 5